Inverted Humus Mounds: Follow-up Field Assessments

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ABSTRACT

As part of the Forest Resource Development Agreement Project 1.10, a series of site-preparation trials was established on four sites by the British Columbia Ministry of Forests (MOF) and the Canadian Forestry Service (now Forestry Canada), Pacific Forestry Centre in 1986. One of the treatment options on these sites is the formation of inverted humus mounds. Three implements were used to create mounds: the Sinkkilä HMF scarifier, the MOF-developed mounder (Ministry mounder), and the Bräcke mounder.

Field assessments of the mounds produced by these implements consisted of three phases: measurement and classification in the fall 1986; remeasurement to document settling over the winter prior to planting in the spring 1987; and classification of soil cores taken adjacent to the planting positions in spring 1988. This report includes the results from the latter two phases.

The 1987 assessment provided information about the effect of winter and spring moisture saturation and freeze-thaw cycles on the mounds. Generally, the erosion and settling of the mounds was less than expected. The Iron Creek and Stewart Lake locations had minimal change, but Mackenzie showed a change in mound height that was significantly different from the more-northern locations. Because slash and vegetation were present on this site, contact between the mounds and the ground was less complete than at Iron Creek and Stewart Lake. Over the winter and spring period, the softening of the saplings and the beginning of decomposition, plus the weight of the saturated soil and organic mass, improved this contact and reduced the mound height.

When compared, the mounds created by the Sinkkilä and Ministry mounder showed significantly greater change than the mounds created by the Bräcke mounder. This could be due to both the relative sizes of the mounds and therefore their potential to settle, and the method of mound formation.

When the 1988 mound heights were compared to the 1986 measurements, the reduction in height was quite dramatic for the larger mounds. Mounds created by all three machines had height reductions averaging greater than 10 cm, except the Sinkkilä and Bräcke mounds at Iron Creek. This change was due primarily to the planters using their boots and shovels to prepare a sloped planting spot. Planting location averaged 4.2 to 5.2 cm less than mound height at the three sites. When implements were compared, this difference averaged 3.1 cm for the Bräcke mounder, 4.5 cm for the Sinkkilä, and 6.0 cm for the Ministry mounder.

Keywords: site preparation, mechanical method, mounding, patch scarifiers, evaluation, Bräcke mounder, Sinkkilä HMF scarifier, MOF mounder.

PREFACE

This study was funded jointly by the Canada/British Columbia Forest Resource Development Agreement (FRDA) Extension, Demonstration, Research & Development Sub-program and the Forest Engineering Research Institute of Canada (FERIC). The study was carried out in cooperation with FRDA Research Project 1.10.

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The author is grateful for the assistance provided by R.G. McMinn (consultant), Victoria; L.R. Bedford (FRDA 1.10 Project Leader); J. Thornton (MOF), Victoria; C. Hackinen (soils consultant), Burnaby; and D. Bryce (contractor), Prince George. She is also appreciative of the data analysis and report preparation assistance of FERIC personnel M.A. von der Gönna, J. Kraan, K. Patton, K. Prochnau, and J. Tan.

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1 INTRODUCTION

As part of the Forest Resource Development Agreement (FRDA) Extension, Demonstration, Research & Development Sub-program Project 1.10, a series of site-preparation trials was established by the British Columbia Ministry of Forests (MOF) and the Canadian Forestry Service (CFS) (now Forestry Canada), Pacific Forestry Centre (PFC) in 1986. These trials were located in four areas and consisted of mechanical, herbicide, and fertilizer treatments. Biological assessments and ecophysiology studies are ongoing on these sites.

One of the treatment options on these areas is the formation of inverted humus mounds. Three implements were used to create mounds for evaluation: the Sinkkilä HMF scarifier, the MOF-developed mounder (Ministry mounder), and the Bräcke mounder. The objective of the FERIC study was to compare the effectiveness of these implements in preparing acceptable mounds and to document changes to mound size after several winters and after the planting phase.

Field assessments of the mounds produced by the implements consisted of three phases: the initial classification of the mounds in the fall 1986 (Hedin 1987); remeasurement to document settling over the winter prior to planting in the spring 1987; and classification of soil cores taken adjacent to the planting positions in spring 1988. This report includes the results from the latter two phases.

2 DESCRIPTION OF SITES

Four sites were chosen by MOF and CFS to test site-preparation treatments in 1986. These sites were representative of areas where cold, moist soils and competitive vegetation hamper seedling establishment. The site descriptions are summarized in Table 1.

TABLE 1. Characteristics of treated sites[a]

Location	Biogeoclimatic subzone/variant[b]	Humus[c]	Soil texture[c]	Moisture regime	Pretreatment condition
Iron Creek, northwest of Fort St. John	Iron Creek Graham River Wet Cold Boreal White and Black Spruce (BWBSwc2)	Moder humus forms; moderate to very deep humus (10-52 cm)	Silty clay loam and clay loam	Mesic to hygric	Windrow scarified in 1985; no slash; herbaceous vegetation and grass
Stewart Lake, west of Dawson Creek	Stewart Lake Peace River Moist Warm Boreal White and Black Spruce (BWBSmwl)	Moder humus forms; moderate to deep humus (9-24 cm)	Silty clay loam, clay loam and silt loam	Subhygric to hygric	Windrow scarified in 1986; no slash; herbaceous vegetation and grass
Mackenzie	Mackenzie Finlay-Peace Wet Cool Sub-Boreal Spruce (SBSwk2)	Mull, moder and mor humus forms; thin to very deep humus (2-38 cm)	Silt loam including some pockets with greater clay content	Submesic to subhydric	Logged in 1977; herbaceous and woody vegetation; light slash
Kluskus southwest of Vanderhoof	Kluskus Moist Cold Sub-Boreal Spruce (SBSmc3)	Moder and mor humus forms; thin to moderately deep humus (3-17 cm)	Silt loam with isolated sandy pockets; high coarse fragment content	Mesic	Logged in 1977; herbaceous and woody vegetation; light slash

[a] This information is derived from site characteristics provided by MOF and contract consultants.

[b] Ecosystem classification is from DeLong *et al.* 1985, DeLong *et al.* 1986, and Jang *et al.* 1986.

[c] Hackinen, C. 1987. Soil texture and humus depth/form site profiles for FRDA 1.10 sites. Silviculture Branch. Internal MOFL Report. 19 p.

3 DESCRIPTION OF MOUNDING EQUIPMENT

The three implements used in these trials, the Sinkkilä HMF scarifier, the Ministry mounder, and the Bräcke mounder, have been described in Hedin (1987). More information is available in Coates and Haeussler (1987), from the author, or from Lorne Bedford, MOF.

4 MOUND ASSESSMENT PROCEDURE

The layout of the study areas was described in Hedin (1987). The reassessments for this study were carried out on mounds classified as "acceptable" in the fall 1986 assessment. These acceptable mounds were staked for identification during remeasurement.

The spring 1987 assessment included the measurement of mineral-soil capping depth and mound height for comparison with the fall 1986 measurement.

The spring 1988 measurements included height of mound and planting height. Two soil cores were taken adjacent to the seedling in order to document the immediate root environment. Each layer within the soil cores was classified as mineral soil, Ah horizon, humus, litter, or combination mineral soil and organic material. This latter category was used when the material was combined through the action of the site-preparation implements or the previous windrowing. Depth and type of layer were recorded sequentially. This information was then used to classify the planting spot using a modification of the original classification system (Appendix I).

Figure 1 shows the height measurements that were taken on the mounds from 1986 to 1988. More information on the methodology can be obtained from the author or Lorne Bedford, MOF.

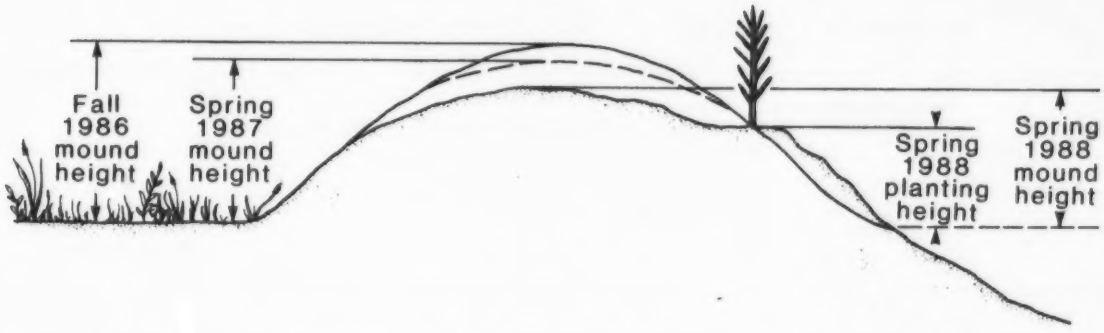

FIGURE 1. Schematic of mound illustrating height measurements taken 1986 to 1988.

5 POST-WINTER MOUND-ASSESSMENT RESULTS

5.1 Mound Class

The fall 1986 and spring 1987 mound-assessment results are shown in Tables 2 to 4 for each of the three implements. Contingency table analysis was done to determine if overwintering resulted in significant changes in mound-class distribution. Fall and spring classifications were compared using acceptable and unacceptable categories (defined in Appendix 1). Each implement at each location was tested with the contingency table analysis. With one exception, all results showed no significant change at the 95% confidence level.

The Bräcke mounder at Stewart Lake showed a significantly larger number of acceptable mounds in the spring compared to the fall classification. Individual mound data were examined to identify the reason for this difference. Fifteen mounds, 7.5% of the sample, had been classified as "mineral soil over

undisturbed organic material" (unacceptable) in the fall of 1986. In the spring reassessments, these mounds were placed in various acceptable mound classes as "mineral soil over inverted organic material." The Bräcke mounder forms its mounds in a two-step process. The inversion of the organic material may be erratic and placement of mineral soil may not be precise upon the inverted material. The mounds are relatively low in height and less distinct compared to mounds formed by the other two implements. During the winter, closer contact between the layers was established. This, combined with the death and partial decomposition of the vegetation buried beneath the mound, made it difficult to judge between inverted and undisturbed humus. Consequently the classification occasionally gave results different from those obtained the previous year.

TABLE 2. Mound classes - Sinkkilä HMF scarifier

	% of total samples					
	Iron Creek		Stewart Lake		Mackenzie	
	Fall 1986	Spring 1987	Fall 1986	Spring 1987	Fall 1986	Spring 1987
Mineral-soil capping ≥10 cm	22	30	53	30	4	6
Other acceptable mounds	60	50	27	51	40	40
Total acceptable mounds	82	80	80	81	44	46
Unacceptable attempts	18	20	20	19	56	54
Total	100	100	100	100	100	100

TABLE 3. Mound classes - Ministry mounder

	% of total samples							
	Iron Creek		Stewart Lake		Mackenzie		Vanderhoof	
	Fall 1986	Spring 1987	Fall 1986	Spring 1987	Fall 1986	Spring 1987	Fall 1986	Spring 1987
Mineral-soil capping≥10 cm	62	71	89	87	79	75	65	68
Other acceptable mounds	17	11	6	10	15	20	27	23
Total acceptable mounds	79	82	95	97	94	95	92	91
Unacceptable attempts	21	18	5	3	6	5	8	9
Total	100	100	100	100	100	100	100	100

TABLE 4. Mound classes - Bräcke mounder

	% of total samples					
	Iron Creek		Stewart Lake		Mackenzie	
	Fall 1986	Spring 1987	Fall 1986	Spring 1987	Fall 1986	Spring 1987
Mineral-soil capping ≥ 10 cm	6	18	41	26	18	13
Other acceptable mounds	65	58	39	63	52	64
Total acceptable mounds	71	76	80	89	70	77
Unacceptable attempts	29	24	20	11	30	23
Total	100	100	100	100	100	100

Contingency table analysis was also done to examine if there was a change in type of acceptable mounds; that is, was there a difference in the depth of mineral-soil capping between the fall and spring assessments. Ten centimeters of mineral-soil capping was used as the separation point. The Bräcke mounder at Iron Creek and Stewart Lake showed a significant difference in distribution of mounds above and below 10-cm capping between the two seasons. As described earlier, when comparing acceptable and unacceptable mounds, the Bräcke mounder's process of mound creation makes classification much less straightforward than classifying mounds formed by the Sinkkilä or Ministry mounder. At Iron Creek, the Bräcke results showed more mounds in classes of greater than 10-cm mineral-soil capping in the spring than in the fall. The results may be due to the classification method; mineral-soil capping depth is determined after several shovel openings of the mound have been made. The majority of Bräcke mounds are in the classes on either side of the 10-cm capping, and depth samples could vary sufficiently to affect classification.

At Stewart Lake, assessments of the mounds made by the Bräcke mounder showed that in the spring fewer mounds were in the greater than 10-cm class than in the fall. The reason may be similar to that stated in the discussion above, but at Stewart Lake the Sinkkilä also showed a significant decrease in the number of mounds in the deeper capping classes. The soil on this site may have been more susceptible to weathering than at Iron Creek.

The Ministry mounder did not show any significant changes in mound class. Mineral-soil cappings were generally well over the 10-cm depth and any overwintering changes did not affect the classification.

At Iron Creek, mounds produced by all implements showed deeper mineral-soil capping after the winter. One explanation may be the filtering of fine mineral-soil particles into the well-decomposed humus. Often the Ah and humus were difficult to distinguish and additional mineral particles would have indicated a deeper capping. This filtering of mineral soil through the mound can be expected to occur over time.

5.2 Mound Height

The heights of acceptable mounds were measured both in the fall 1986 and in the spring 1987. Settling and erosion were expected to occur as the mounds became saturated and were exposed to freeze and thaw cycles. Table 5 summarizes the mound heights for the two assessments. The Ministry of Forests, Research Branch, conducted analysis of variance on the change in mound height over the winter at the Iron Creek, Stewart Lake, and Mackenzie sites (Table 6). The results showed that there were significant differences between locations and between implements (at 95% confidence).

TABLE 5. Average mound height of acceptable mounds before and after winter settling (cm)

	Location							
	Iron Creek		Stewart Lake		Mackenzie		Vanderhoof	
	Fall 1986	Spring 1987	Fall 1986	Spring 1987	Fall 1986	Spring 1987	Fall 1986	Spring 1987
Sinkkilä	31	29	34	33	32	26	-	-
Ministry mounder	36	36	36	34	35	29	27	23
Bräcke mounder	20	20	22	21	23	19	-	-

TABLE 6. Change in mound height (fall height minus spring height), Duncan's multiple range test

	Location		
	Mackenzie	Stewart Lake	Iron Creek
Mean All implements	5.3 cm	1.6 cm	0.6 cm
Implement	Ministry mounder[a]	Sinkkilä	Bräcke mounder
Mean All locations	3.2 cm	3.2 cm	1.3 cm

Note: Means with the same underline are not significantly different at p = 0.05.
[a] Excluding the Vanderhoof location.

At Iron Creek and Stewart Lake, the overall change in mound height was relatively small (0.6 to 1.6 cm) and there was not a significant difference between the two locations. Both sites had fine-textured soils and had been brush-bladed. Mound-to-ground contact had been good from the time of treatment. Limited movement of soil, due to slumping, was observed. In some cases, the sharp edges of mounds became less distinct, but overall soil movement was minimal. The surfaces of some mounds with a high clay component, especially at Stewart Lake, had dried into a structure with small blocks, easily eroded by kicking or similar action. With the absence of such force, however, the mounds remained intact.

At Mackenzie, the difference between the fall 1986 and the summer 1987 height measurements varied significantly from Stewart Lake and Iron Creek. The sites themselves were very different in terms of history, vegetation, and soil conditions. Overall change in mound height at Mackenzie was 5.3 cm. Many mounds had adequate but imperfect contact with the undisturbed ground surface. Vegetation, slash material, loose humus, and litter prevented full contact. These mounds had the potential for settling as they became saturated and the buried vegetation began to decay. Stewart Lake had a somewhat greater change in mound height than did Iron Creek although the difference was not significant. The reduction may have been due to differences in soil erodibility.

The Bräcke mounder had less change in mound height than the other two implements. This may be attributed to a smaller overall mound size. Less loose material would be incorporated, and the mound would have less weight and settling potential.

Both the Sinkkilä and the Ministry mounder create mounds with a similar overturning action. This allows material to be folded into the mound. Subsequent saturation of the mineral soil and organic material will compact the mound and reduce the height. The Ministry mounder was equipped with a V-blade and incorporated less slash or vegetation in the mounds it produced. Any effect of this on settling was not evident.

At Vanderhoof, the mounds formed by the Ministry mounder showed an average reduction in height of 4 cm. This was one of the larger values revealed by the follow-up study.

6 POST-PLANTING ASSESSMENT

All four locations were planted operationally in the spring 1987, following the 1987 mound assessments. Two experienced planters were contracted by the MOF to plant all the sites and treatments. The planters were instructed to plant on the mounds, but had the flexibility to choose the microsite. The instruction was to plant the seedlings with the roots extending into the mineral soil under the inverted and undisturbed organic layers, if possible (Figure 2). Therefore, seedlings were frequently buried with their root collars below the surface in larger mounds. Even so, seedling roots were often not deep enough. Standard-size styroplugs, PSB 211 and PSB 313, do not have root lengths capable of reaching through deep capping. The planting contractors used their boots and shovels to break up the larger mounds and to provide a sloped planting site with less mineral soil capping.

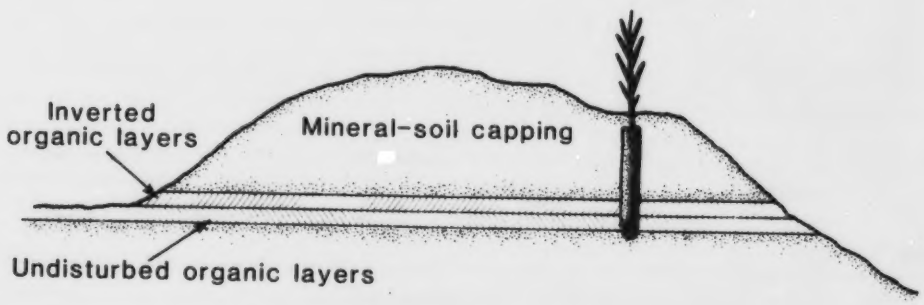

FIGURE 2. Position of seedling planted in large mound.

6.1 Classification of Soil Cores

The primary objectives of the 1988 soil-core classification was to provide detailed information on microsites for the biological components of the total study. Although the soil cores were classified into similar categories, using rules derived from the original mound classification, the 1986 and 1988 data cannot be directly compared. The results of the biological assessments will determine the most effective mineral-soil capping and mound configuration.

Summaries of the soil-core classification are reported in Figures 3, 4, and 5.

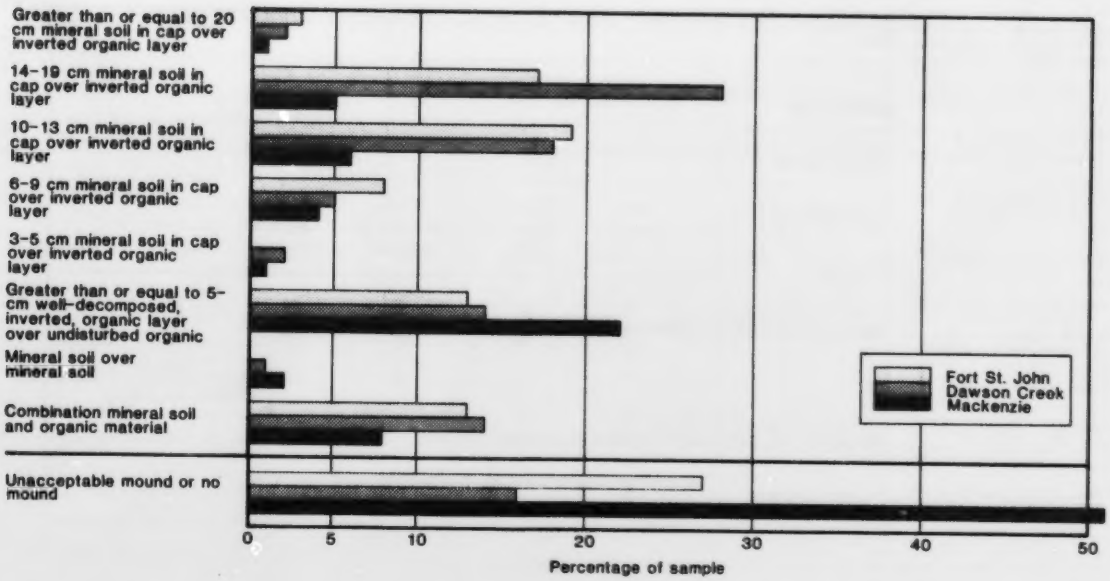
Greater than or equal to 20 cm mineral soil in cap over inverted organic layer
14–19 cm mineral soil in cap over inverted organic layer
10–13 cm mineral soil in cap over inverted organic layer
6–9 cm mineral soil in cap over inverted organic layer
3–5 cm mineral soil in cap over inverted organic layer
Greater than or equal to 5-cm well-decomposed, inverted, organic layer over undisturbed organic
Mineral soil over mineral soil
Combination mineral soil and organic material
Unacceptable mound or no mound
Fort St. John
Dawson Creek
Mackenzie
0
5
10
20
30
40
50
Percentage of sample

FIGURE 3. Classification of soil cores, spring 1988 - Sinkkilä HMF scarifier.

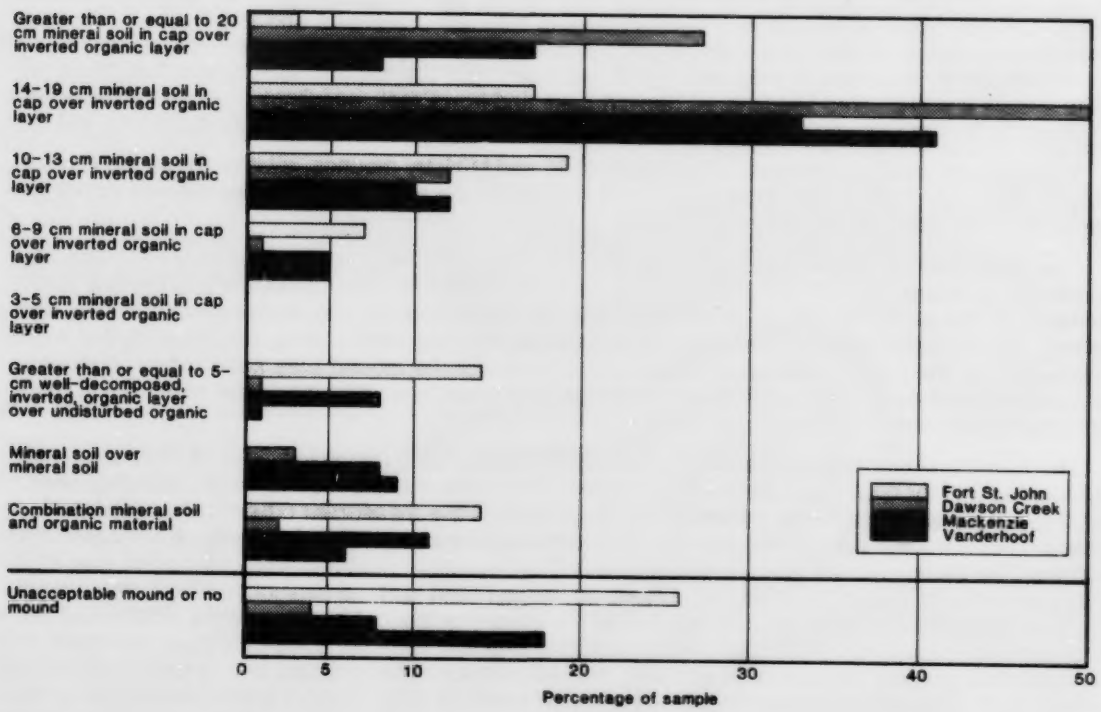
Greater than or equal to 20 cm mineral soil in cap over inverted organic layer
14–19 cm mineral soil in cap over inverted organic layer
10–13 cm mineral soil in cap over inverted organic layer
6–9 cm mineral soil in cap over inverted organic layer
3–5 cm mineral soil in cap over inverted organic layer
Greater than or equal to 5-cm well-decomposed, inverted, organic layer over undisturbed organic
Mineral soil over mineral soil
Combination mineral soil and organic material
Unacceptable mound or no mound
Fort St. John
Dawson Creek
Mackenzie
Vanderhoof
0
5
10
20
30
40
50
Percentage of sample

FIGURE 4. Classification of soil cores, spring 1988 - Ministry mounder.

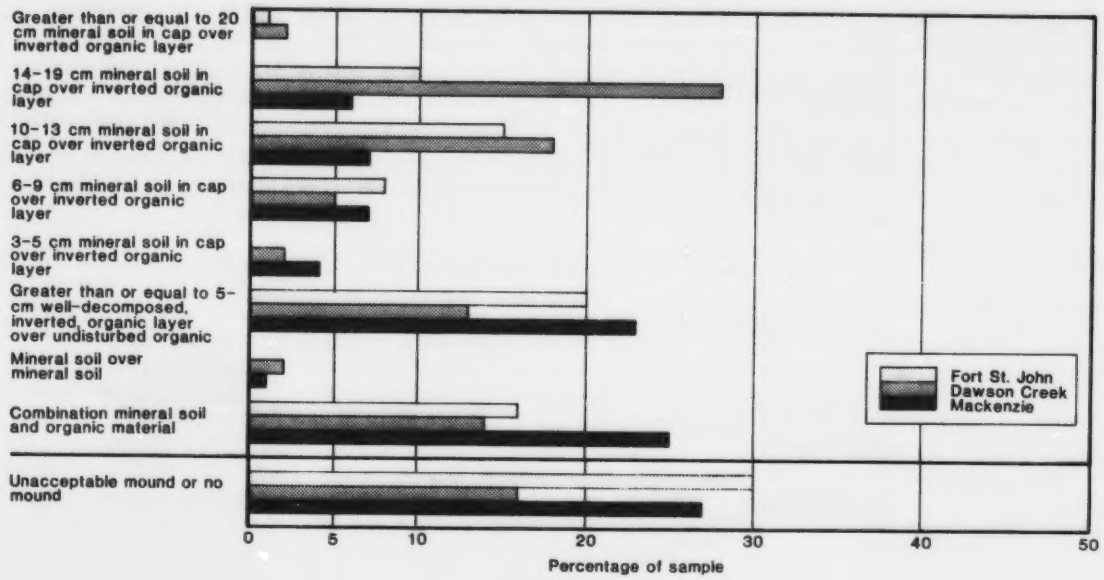
Greater than or equal to 20 cm mineral soil in cap over inverted organic layer
14-19 cm mineral soil in cap over inverted organic layer
10-13 cm mineral soil in cap over inverted organic layer
6-9 cm mineral soil in cap over inverted organic layer
3-5 cm mineral soil in cap over inverted organic layer
Greater than or equal to 5-cm well-decomposed, inverted, organic layer over undisturbed organic
Mineral soil over mineral soil
Combination mineral soil and organic material
Unacceptable mound or no mound
Fort St. John
Dawson Creek
Mackenzie
0
5
10
20
30
40
50
Percentage of sample

FIGURE 5. Classification of soil cores, spring 1988 - Bräcke mounder.

6.2 Mound and Planting Heights

Mound and planting heights were measured for each of the sampled mounds (Figure 1). Table 7 summarizes the average mound and planting heights for each implement and site location. In most cases, the difference between the 1988 mound heights and planting heights was less than 5 cm. Such differences can be attributed to the planting process, opening of the slit, and subsequent tamping of the soil to ensure a well-planted seedling. At Stewart Lake and Iron Creek, seedlings were often planted on the sloped side of the mound in order to place the root plug into the underlying humus or mineral soil.

The elevated position of trees planted on Sinkkilä and Ministry mounds, relative to ground level, is evident. Although planting microsites were not at the tops of the mounds, they were still well above the Bräcke mounds, often twice as high.

The 1986 mound heights were much greater than the 1988 heights. In most cases the average difference was more than 10 cm. Unfortunately, it is not possible to distinguish the change due to the planters' influence on the mound configurations from the change due to accelerated slumping and settling. Visual observation suggests slumping in the second year was greater, and mounds that were undisturbed by the planters remained intact. An opening of the mound may have removed surface compaction resulting from mounding during wet ground conditions, and made the mineral soil more susceptible to erosion.

The General Linear Models Procedure of the SAS Programming Language (SAS Institute Inc. 1985) was used to test for differences between machines and locations using mound height, planting height, and the difference between mound and planting heights as the measures. The results are shown in Table 8. There was no significant interaction between machine and location, but there were location and machine differences.

TABLE 7. Average mound and planting heights for each implement and location (cm)

	Implement								
	Sinkkilä			Ministry mounder			Bräcke mounder		
Location	1986 mound height	1988 mound height	1988 planting height	1986 mound height	1988 mound height	1988 planting height	1986 mound height	1988 mound height	1988 planting height
Iron Creek	31	26	22	36	24	19	20	14	11
Stewart Lake	34	23	17	36	26	19	22	12	9
Mackenzie	32	20	16	35	23	17	23	12	9
Vanderhoof	-	-	-	27	19	15	-	-	-

TABLE 8. Comparison of mound and planting heights (excluding the Vanderhoof location), Duncan's multiple range test (p = 0.05)

	Location			Implement		
1988 mound height:						
	Iron Creek	Stewart Lake	Mackenzie	Ministry mounder	Sinkkilä	Bräcke mounder
Mean	21.1 cm	20.2 cm	18.6 cm	24.4 cm	22.6 cm	12.5 cm
1988 planting height:						
	Iron Creek	Stewart Lake	Mackenzie	Ministry mounder	Sinkkilä	Bräcke mounder
Mean	16.9 cm	15.0 cm	14.3 cm	18.4 cm	18.1 cm	9.4 cm
Difference between mound and planting heights:						
	Stewart Lake	Mackenzie	Iron Creek	Ministry mounder	Sinkkilä	Bräcke mounder
Mean	5.2 cm	4.3 cm	4.2 cm	6.0 cm	4.5 cm	3.1 cm

Note: Means with the same underline are not significantly different.

The 1988 mean-mound heights were similar for the three locations, although the mound heights at Iron Creek were significantly greater than at Mackenzie. This relationship was maintained when planting height was compared. The difference between mound height and planting height was not significantly different over the three locations. The 1988 heights of mounds for the Sinkkilä and Ministry mounder were predictably similar, as was planting height. The Bräcke mounds were significantly smaller, and there was less difference between planting and mound heights. With the Bräcke mounds, the difference in mound and planting heights would be due primarily to the actual planting process, i.e. making the slit and firming the soil. With the lower mounds, the planters would not need to influence the microsite as would be necessary with the larger Ministry mounds and Sinkkilä mounds, and the seedlings could be planted on the top of the mound, giving the roots good contact with the underlying mineral soil.

7 SUMMARY AND CONCLUSION

The 1986 assessment of the mounds produced by the Sinkkilä HMF scarifier, the Ministry mounder, and the Bräcke mounder provided information on the configuration of the mounds soon after treatment. In order to relate seedling survival and growth to the microsite conditions, and, from there, to specify desirable mound configurations, information on the planting microsites is also necessary. Mechanically site-prepared ground is often left over winter before planting to allow any settling of the soil to occur. As well, the planters choose the planting microsite and use their shovels and boots to further prepare the spot and plant the seedling. These activities can all influence the eventual microsite.

The 1987 assessment provided details on the effect of winter and spring moisture saturation and freeze-thaw cycles on the mounds. Generally, the slumping and settling of the mounds was not great. The Iron Creek and Stewart Lake locations had minimal change. Both sites had been windrowed and little slash or vegetation was included within the mounds. Although the soils were fine textured, erosion did not appear to be significant, and the mounds retained relatively unaltered shape. Mackenzie, however, showed a change in mound height that was significantly different from the more northern sites. The mean change in height of 5.3 cm was also meaningful operationally. Because slash and vegetation were present on this site, contact between the mounds and the ground was less complete. Over the winter and spring period, the softening of the saplings and the beginning of decomposition, plus the weight of the saturated soil and organic mass, improved this contact and reduced the mound height. This site receives accumulations of wet snow, compared to the drier snow on the more northern sites. This added weight would also increase the settling at Mackenzie.

When the change in the height of the mounds created by the three implements is compared, mounds created by the Sinkkilä and the Ministry mounder showed significantly greater changes than those created by the Bräcke mounder. This could be due to both the relative sizes of the mounds, and therefore their potential to settle, and the mode of mound formation. Bräcke mounds also included less vegetation.

The changes in mound-class distribution were only occasionally significant. The differences were probably related more to sampling method and analysis than to physical changes in the mounds.

The 1988 assessment, following planting and an additional year for erosion and settling, showed the greatest changes in the mound heights. The soil cores were classified following a variation of the 1986 methods. However, the 1988 results could not be directly compared to the 1986 classes. There were differences, but trends were not evident.

When 1988 mound heights were compared to the 1986 heights, the reduction in height was quite dramatic for the larger mounds. The mounds formed by all three machines underwent height reduction averaging greater than 10 cm, except the Sinkkilä and the Bräcke mounds at Iron Creek. The reason for this difference at Iron Creek is not clear. Because measurements were not done immediately after planting, the relative contributions of planter effort and slumping cannot be separated. The planters redistributed the inverted soil with their shovels and feet. As well, it appears that the breaking open of the mound after the first winter accelerated subsequent erosion. The mounding action may have compacted the surface of the mounds, especially in the wet, heavy soils at Fort St. John, reducing erosion on undisturbed mounds.

The Bräcke mounds were consistently and significantly lower than those produced by the Sinkkilä and Ministry mounder. The Iron Creek mounds were significantly higher than the mounds at Mackenzie; Stewart Lake mounds were intermediate in height and not significantly different from the other locations.

Planting height averaged 4.2 to 5.2 cm less than mound height across the three locations. When implements were compared, the difference between the Ministry mounder at 6.0 cm and the Bräcke mounder at 3.1 cm was significant. The Sinkkilä, at 4.5 cm, was intermediate and not significantly different from the other two implements.

The biological assessments will determine what the differences mean to mechanical site-preparation prescriptions. While several centimeters may be a significant difference statistically, the ability of equipment to operationally create such small differences is unlikely and the impact on the seedlings has yet to be determined. The 1988 measurements will be valuable in the physiological studies. The soil-core measurements describe the root environment more accurately than the earlier measures, and a precise planting height was measured. Planting height and aspect will influence winter damage in the more northern sites. These studies will be reported by MOF and FRDA as results are compiled.

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APPENDIX 1. Classification of mounds and soil cores

Acceptable mound classes

Greater than or equal to 20-cm mineral soil in cap over inverted organic layer

14- to 19-cm mineral soil in cap over inverted organic layer

10- to 13-cm mineral soil in cap over inverted organic layer

6- to 9-cm mineral soil in cap over inverted organic layer

3- to 5-cm mineral soil in cap over inverted organic layer

Greater than or equal to 5-cm well-decomposed inverted organic layer over undisturbed organic

Unacceptable mound classes

Less than or equal to 2-cm mineral soil in cap over inverted organic layer

Less than 5-cm well-decomposed inverted organic layer over undisturbed organic

Inverted organic mound

Organic mound, not inverted

Mineral over undisturbed organic

Mineral mound over mineral soil

Vertical mound

No mound

In the 1988 soil core assessments, the soil cores were categorized by the same criteria as the acceptable mound classes. As well, three additional categories were used:

Both cores combination mineral and organic material

One core combination mineral and organic material, second core mineral soil

One core combination mineral and organic material, second core organic material